Review of Full-Scale Docking Seal Testing Capabilities

Abstract

NASA is developing a new docking system to support future space exploration missions to low-Earth orbit, the Moon, and Mars. This mechanism, called the Low Impact Docking System (LIDS), is designed to connect pressurized space vehicles and structures including the Crew Exploration Vehicle, International Space Station, and lunar lander. NASA Glenn Research Center (GRC) is playing a key role in developing the main interface seal for this new docking system. These seals will be approximately 147 cm (58 in.) in diameter. To evaluate the performance of the seals under simulated operating conditions, NASA GRC is developing two new test rigs: a non-actuated version that will be used to measure seal leak rates and an actuated test rig that will be able to measure both seal leak rates and loads. Both test rigs will be able to evaluate the seals under seal-on-seal or seal-on-plate configurations at temperatures from –50 to 50 °C (–58 to 122 °F) under operational and pre-flight checkout pressure gradients in both aligned and misaligned conditions.

Review of Full-Scale Docking Seal Testing Capabilities

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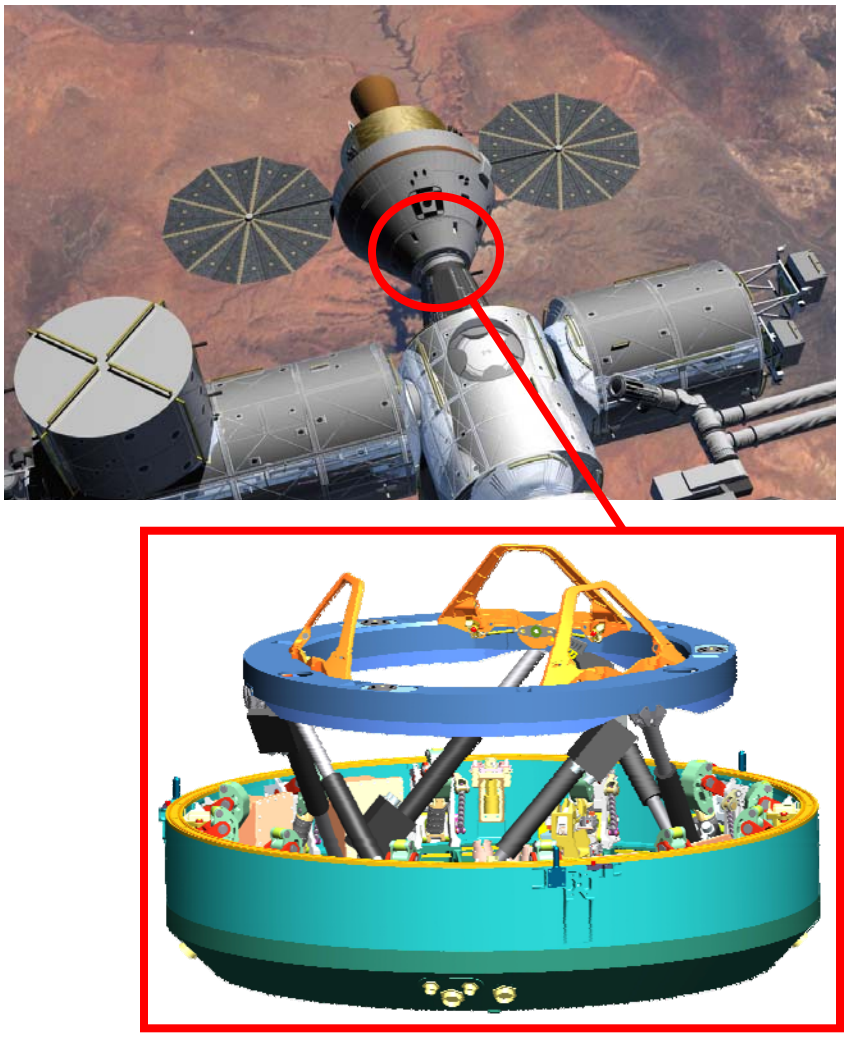
Low Impact Docking System (LIDS)

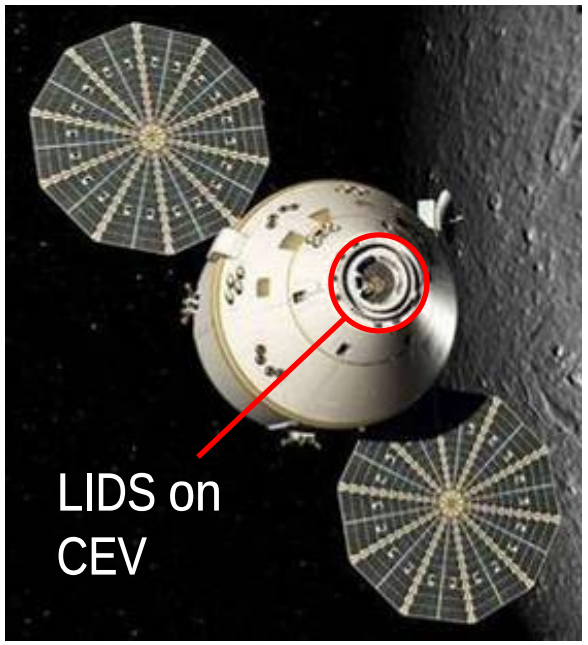
- NASA is developing LIDS as a new docking system to support the Vision for Space Exploration including missions to:
  - International Space Station (ISS)
  - Moon
  - Mars
- LIDS will be an improvement over existing docking systems
  - Reduces impact loads between two mating spacecraft
  - Becomes new Agency standard for docking systems
- Project being led by NASA Johnson Space Center (JSC)

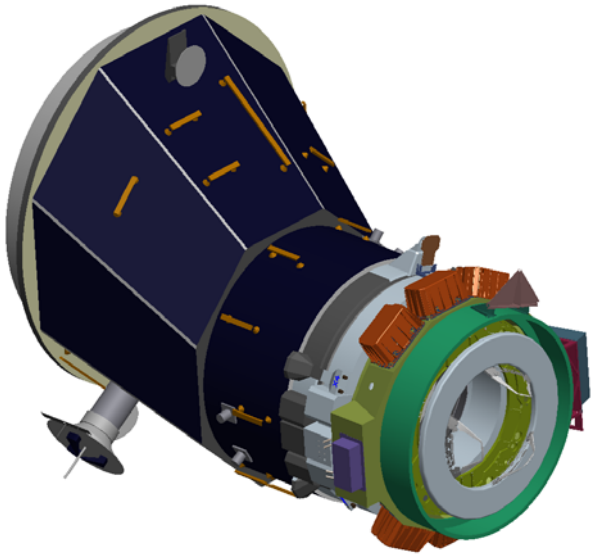


Low Impact Docking System (LIDS)

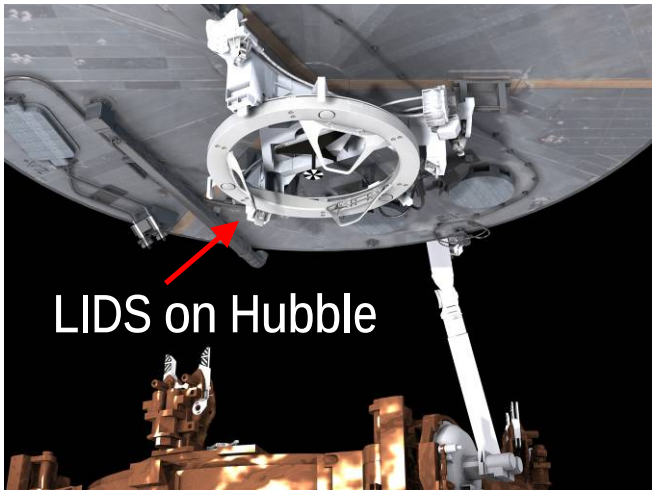
Where will LIDS be Used?

- LIDS will support autonomous rendezvous and mating between:
  - Orion Crew Exploration Vehicle (CEV)
  - International Space Station (ISS) using APAS-to-LIDS Adapter Segment (ATLAS)
  - Altair Lunar Surface Access Module (LSAM)
  - LIDS Hubble Passive Interface (LIDS HST)



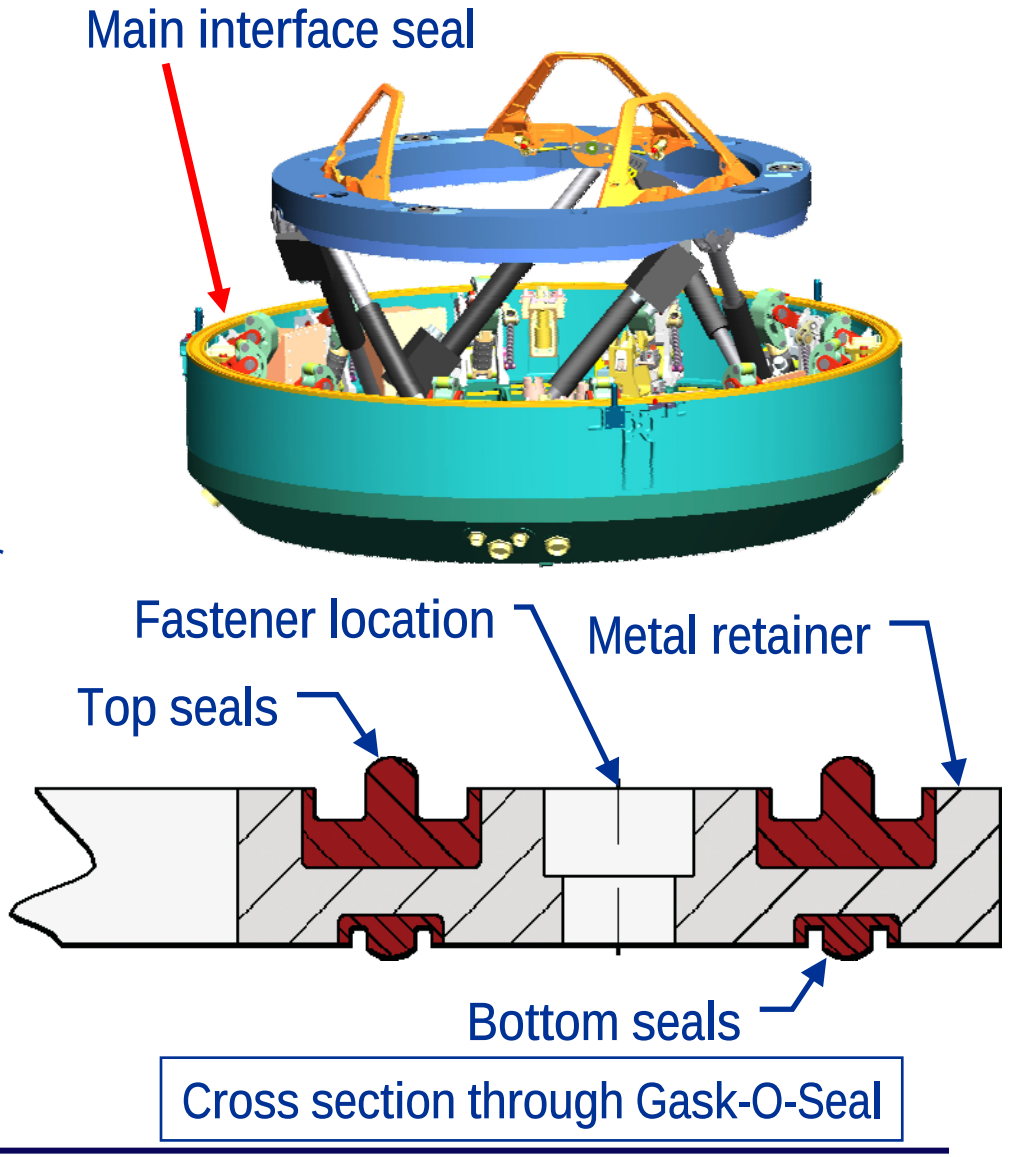


ATLAS on ISS



LIDS Main Interface Seals

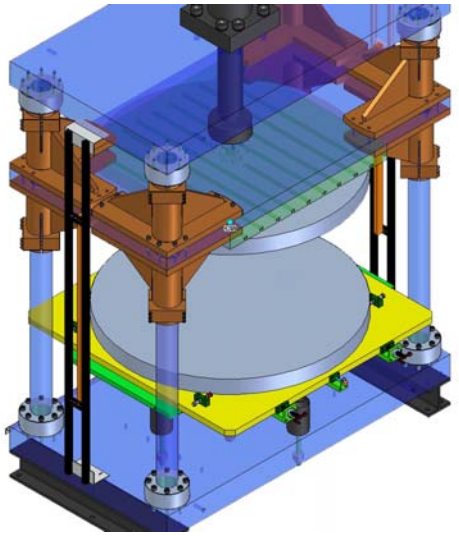
- NASA GRC developing main interface seals for LIDS
- Leading candidate is Gask-O-Seal™ design (Parker Hannifin)
  - Used on Common Berthing Mechanism (CBM), other locations on ISS
  - S0383-70 silicone elastomer bulbs vacuum molded into 6061-T651 aluminum retainer
  - Dual bulbs on top & bottom of retainer
- Dimensions:
  - EDU 58 (Engineering Demonstration Unit) & flight units:
    - 58 in. outer diameter
    - 1.5 in. face width
    - 0.300 +/-0.003 in. retainer thickness
  - EDU 54 (early LIDS prototype):
    - 54 in. outer diameter
    - 1.125 in. face width
    - 0.200 +/- 0.003 in. retainer thickness



Cross section through Gask-O-Seal

Full-Scale LIDS Seal Testing

Full-scale non-actuated LIDS seal test rig

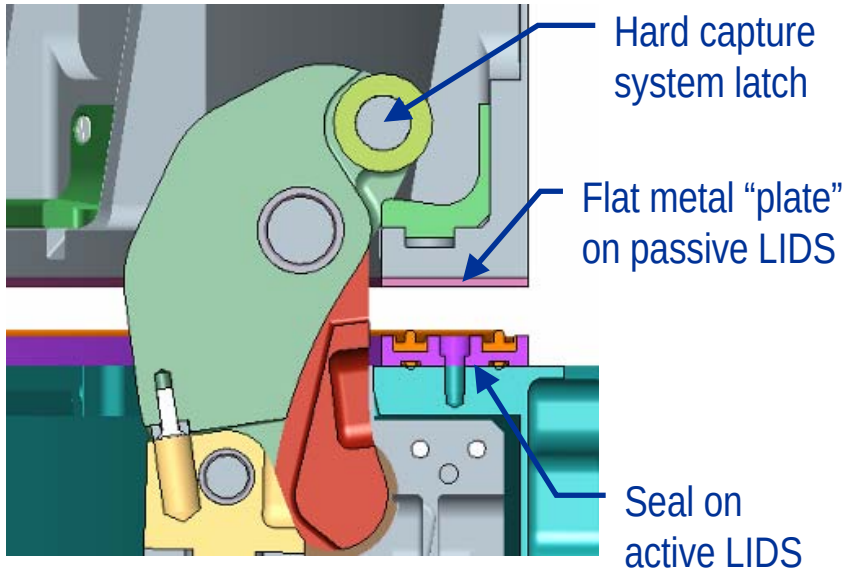


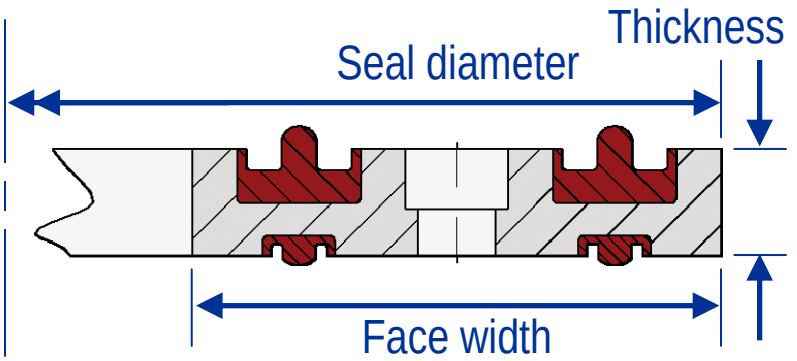
Full-scale actuated LIDS seal test rig

- NASA GRC is developing two new test rigs to evaluate the performance of candidate full-scale LIDS seals under anticipated operating conditions:
  - Non-actuated test rig measures seal leak rates
  - Actuated test rig measures seal leak rates and loads

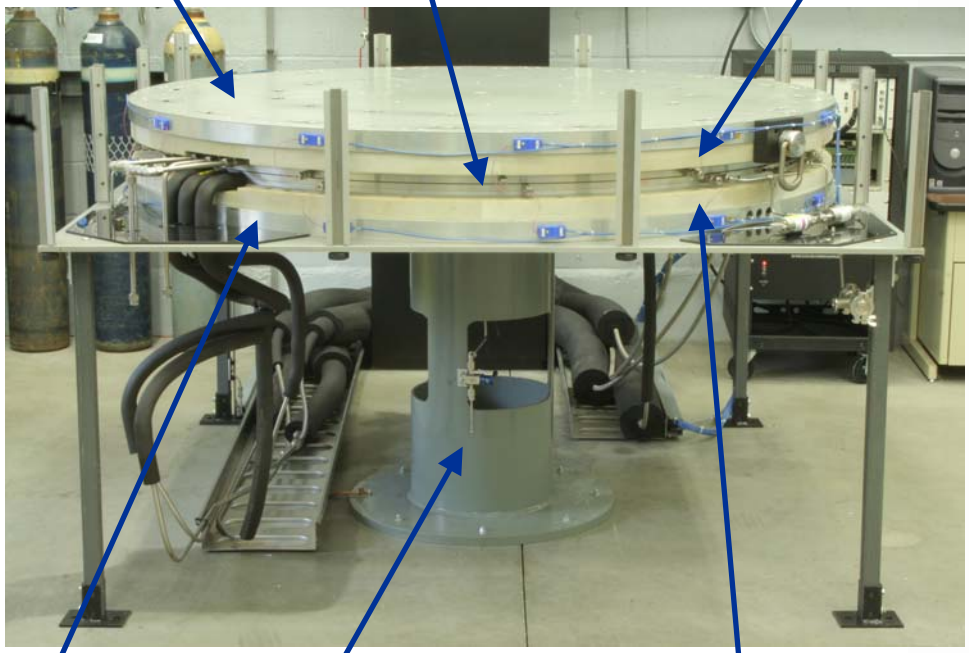
Full-Scale LIDS Seal Testing Requirements

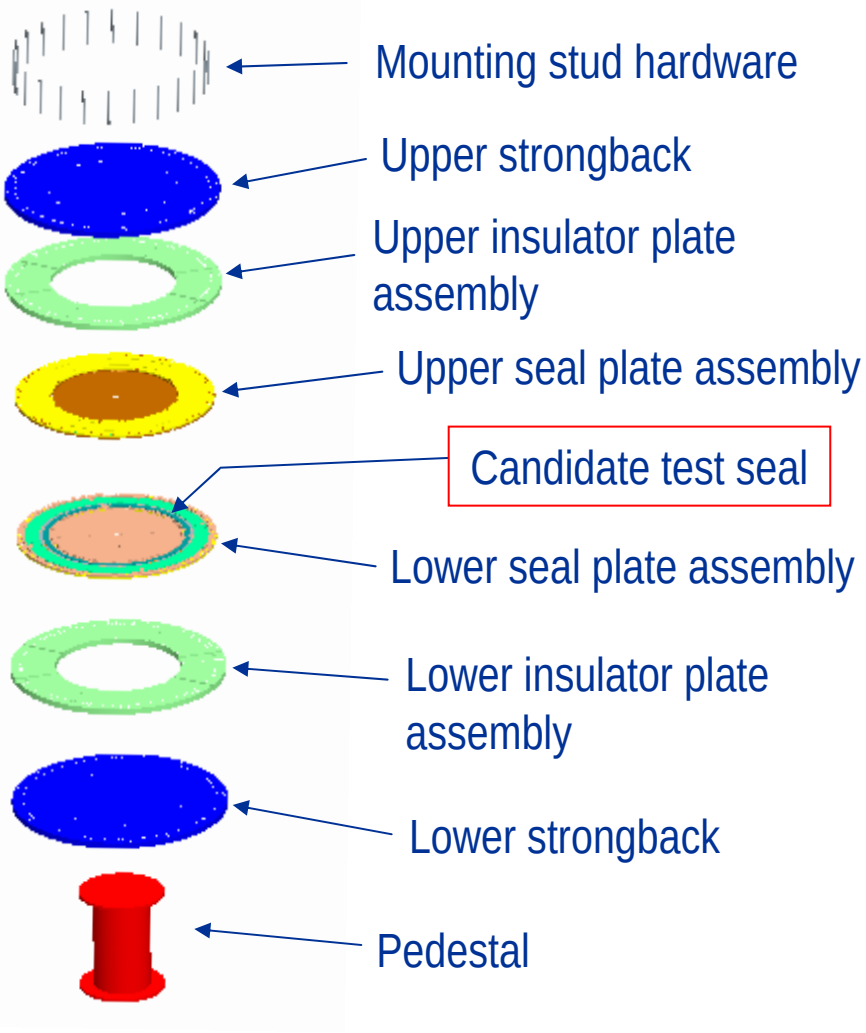
- Test rigs will be capable of evaluating:
  - Seal-on-plate (primary) and seal-on-seal configurations
  - Seals of various designs and sizes:
    - Diameters: 52 to 60 in.
    - Various seal widths and thicknesses
  - Temperatures from -50 to +50°C (-58 to +122°F)
  - Pressure differentials across seals for:
    - Operating conditions in space
    - Pre-flight checkout conditions on ground
  - Aligned vs. misaligned conditions
  - Seal compressive and adhesive loads during docking and undocking (actuated rig only)





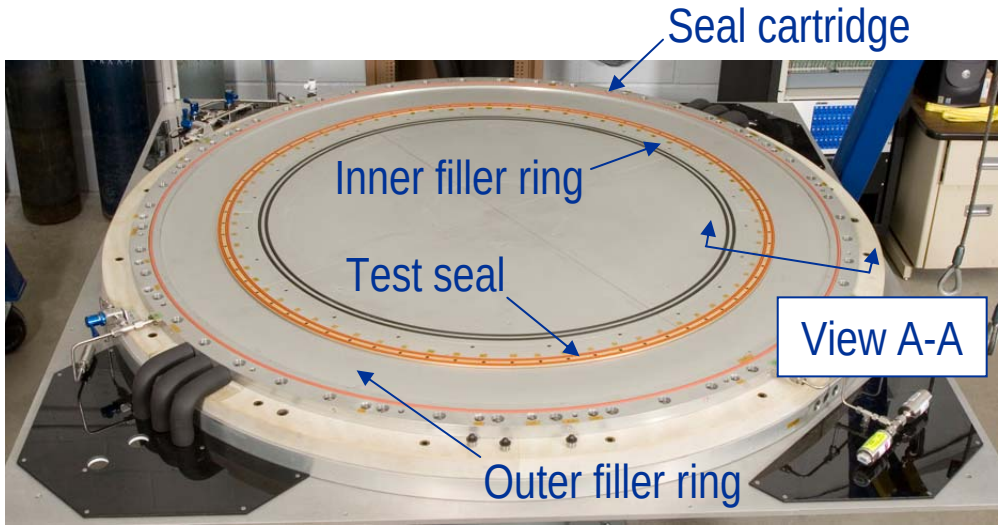
Main Elements of Full-Scale Non-Actuated LIDS Seal Test Rig

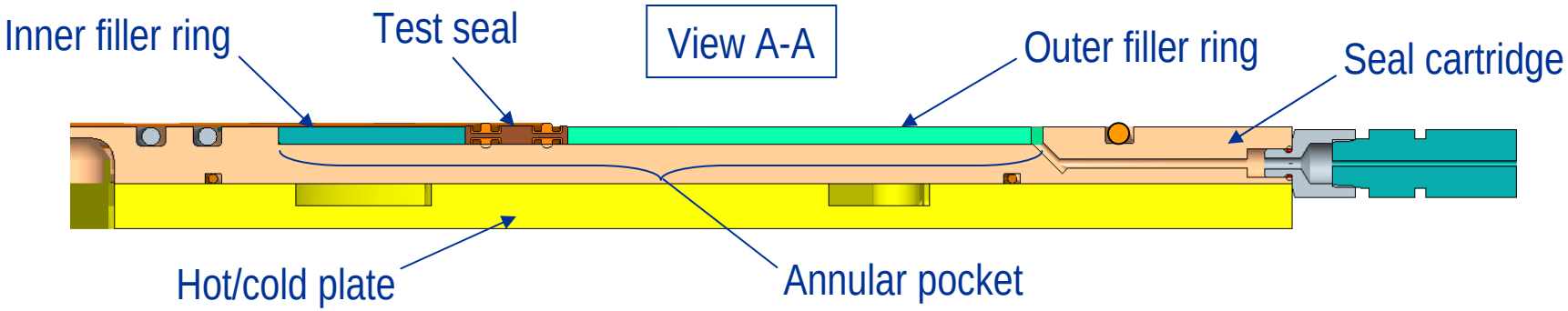




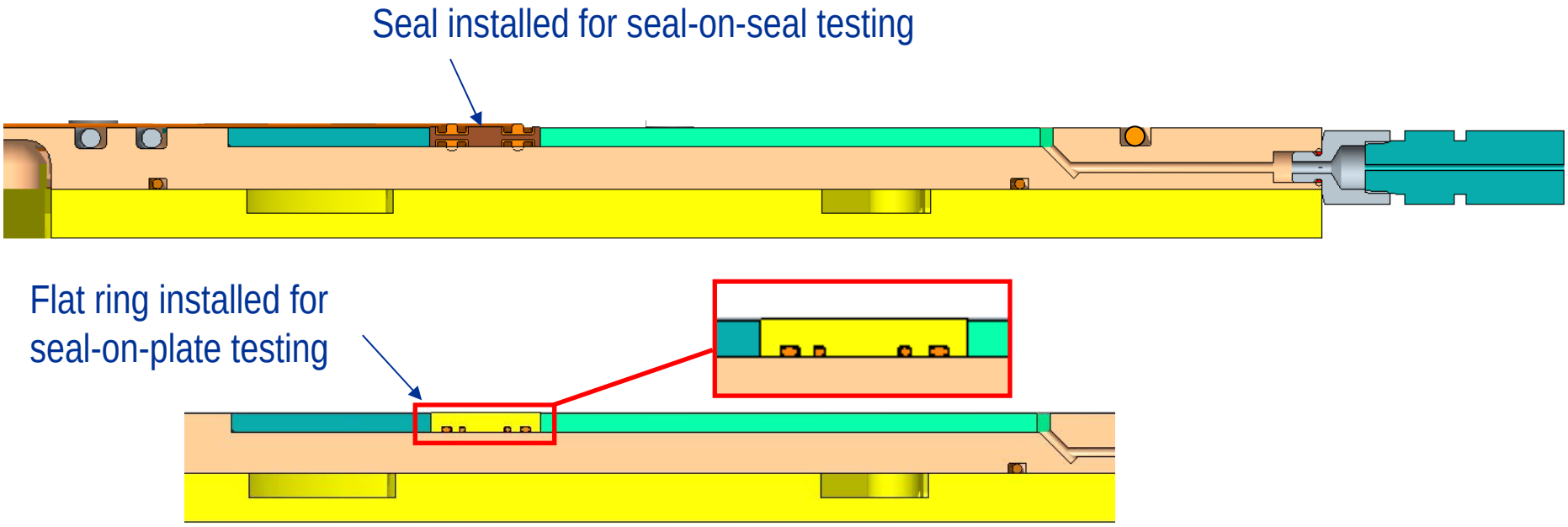
Seal Plate Assemblies and Seal Cartridges

- Seal plate assemblies include:
  - Seal cartridge
  - Inner and outer filler rings
  - Pair of hot/cold plates
- Seal cartridge:
  - Holds seal test specimens
  - Modular design: Wide, annular pocket allows testing of various seal designs:
    - Seal outer diameters: 52 to 60 in.
    - Broad range of seal widths
    - Seal thicknesses of 0.200 in. and 0.300 in.
  - Three alignment pins hold test seal coaxial to centerline of seal plate assembly to within 0.003 in.



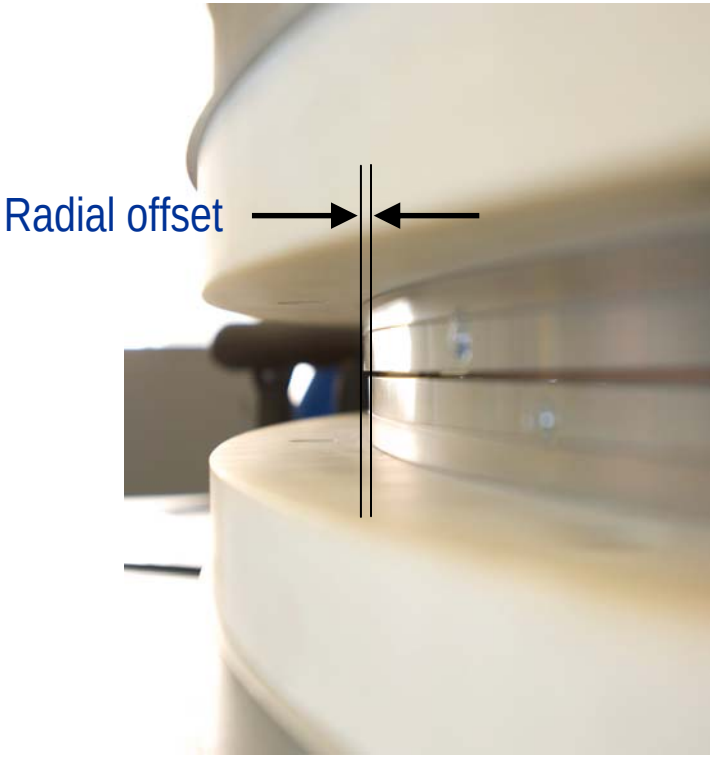


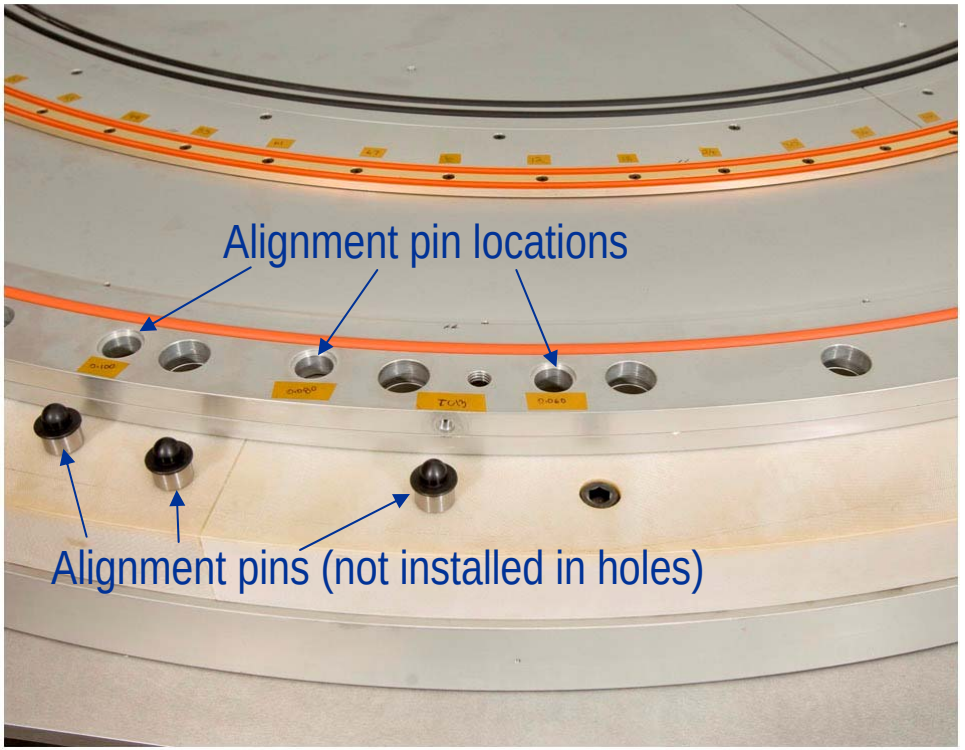
Seal Cartridges: Seal-on-Seal vs. Seal-on-Plate



- Able to perform tests in seal-on-seal and seal-on-plate configurations
- Seals installed in both upper and lower seal plate assemblies for seal-on-seal tests
- Flat ring installed in upper seal plate assembly for seal-on-plate tests. Ring has:
  - Smooth (16 µin), flat upper surface
  - O-ring grooves on lower surface to seal interface between ring and seal cartridge

Seal Cartridges: Radial Offsets

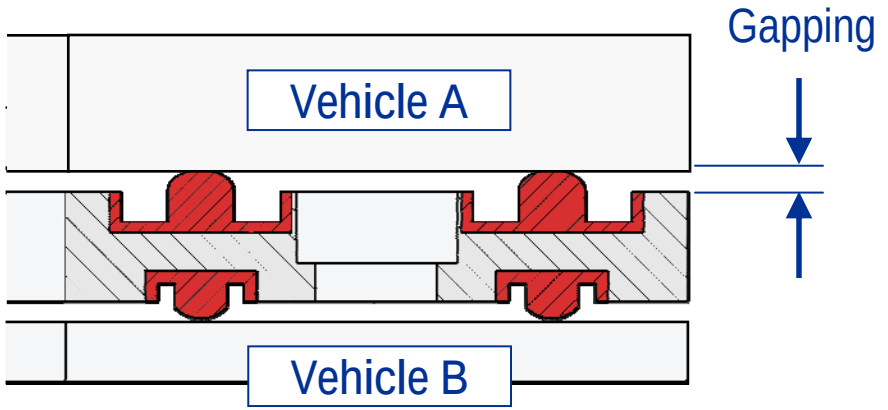


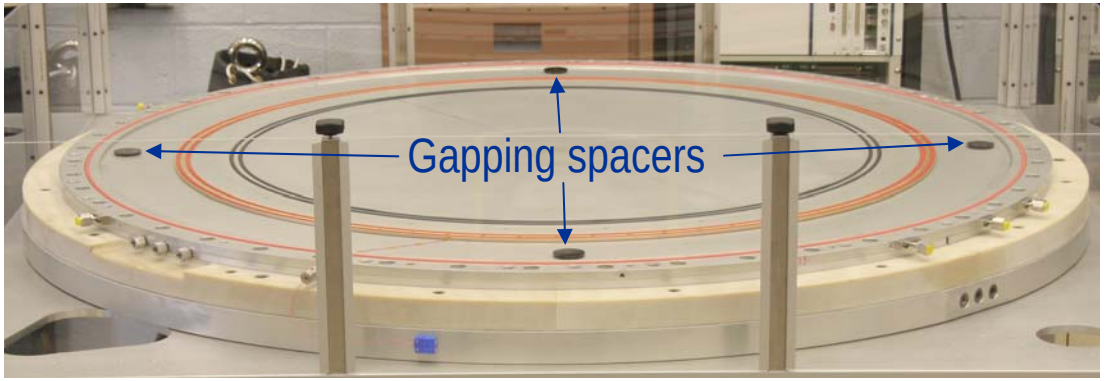


- Seals must accommodate radial offsets caused by tunnel-to-tunnel misalignment (+/- 0.060 in.) and thermal gradients
- Test rig includes sets of three holes and alignment pins to generate various levels of alignment/misalignment:
  - Both seals aligned
  - Radial offsets of 0.020, 0.040, 0.060, 0.080, 0.100, and 0.150 in.

Seal Cartridges: Gapping

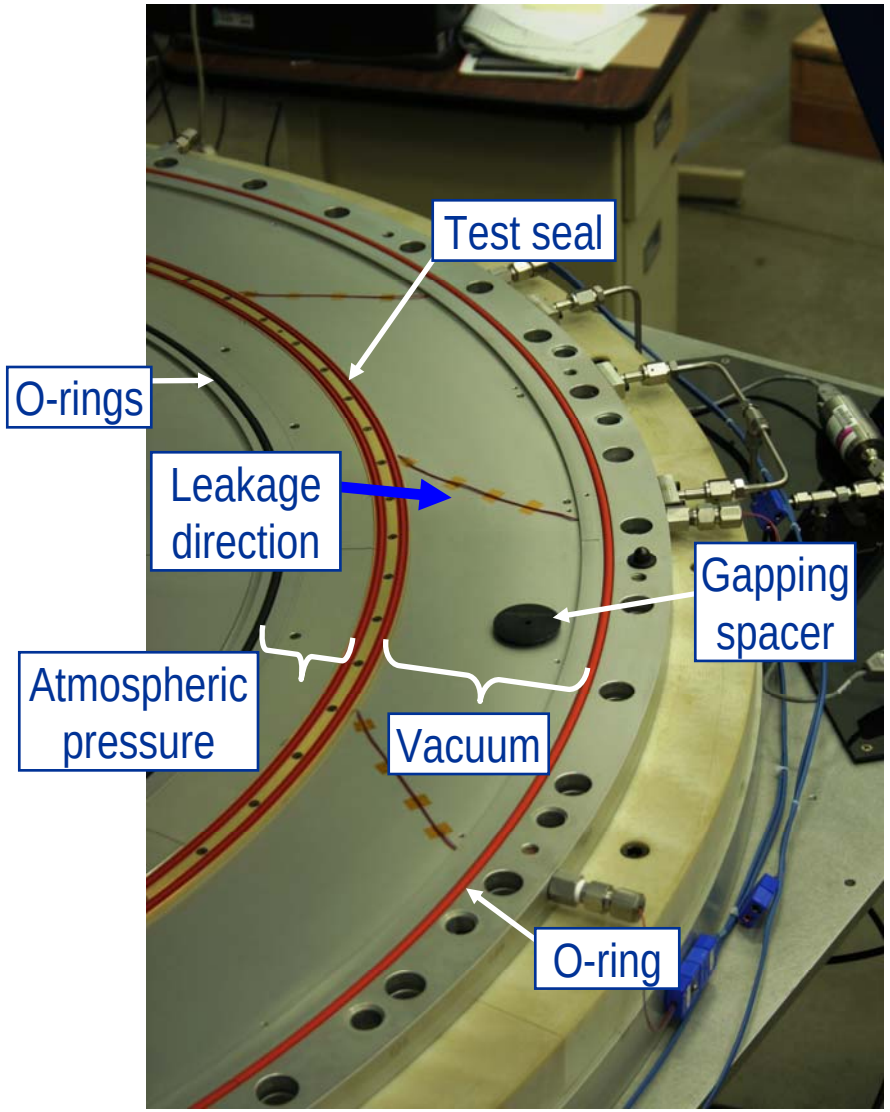
- Seals must accommodate up to 0.010 in. of gapping
- Test rig allows seals to be tested in different configurations:
  - Fully compressed
  - Angled gap
  - Uniform gap
- Spacers installed to create different levels of gapping: 0.010, 0.020, 0.030, and 0.040 in.



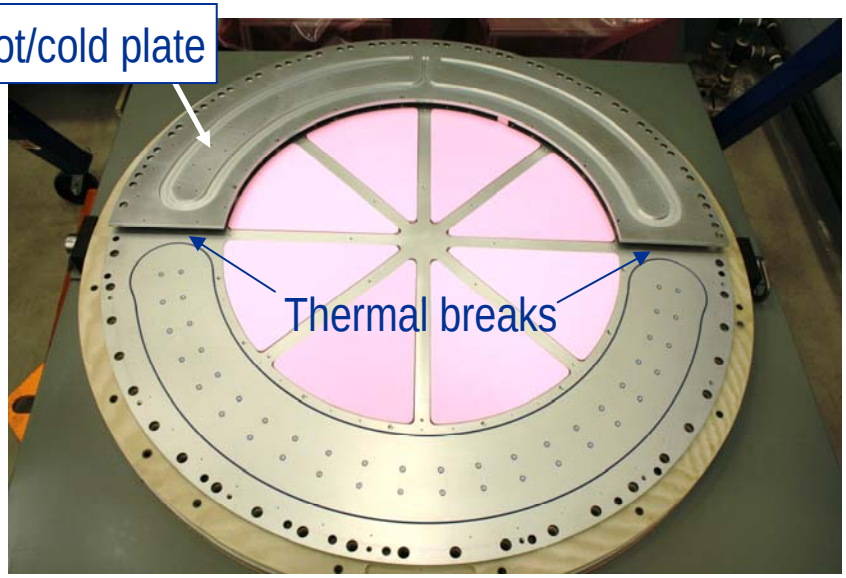


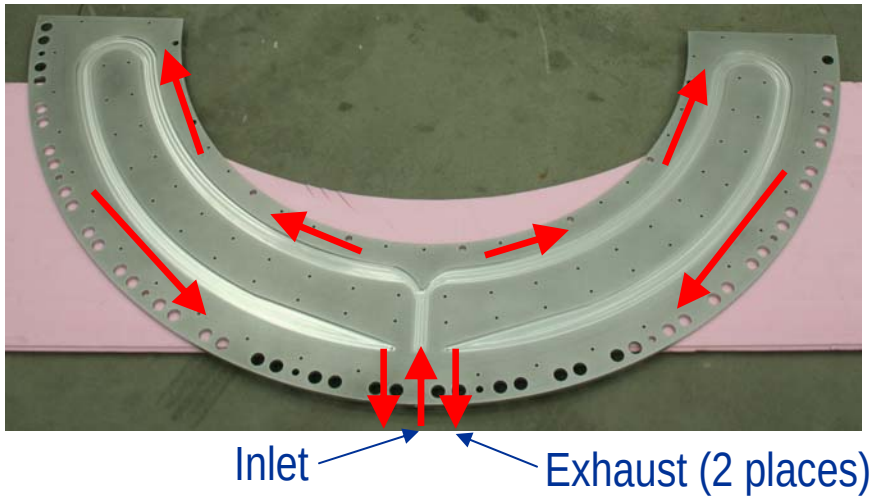
Seal Cartridges: Pressure Conditions

- Lower seal plate assembly includes O-rings to generate desired pressure differentials:
  - Atmospheric pressure inboard of seals
  - Vacuum outboard of seals
- Upper seal cartridge has flat surfaces for O-rings to seal against



Hot/Cold Plates

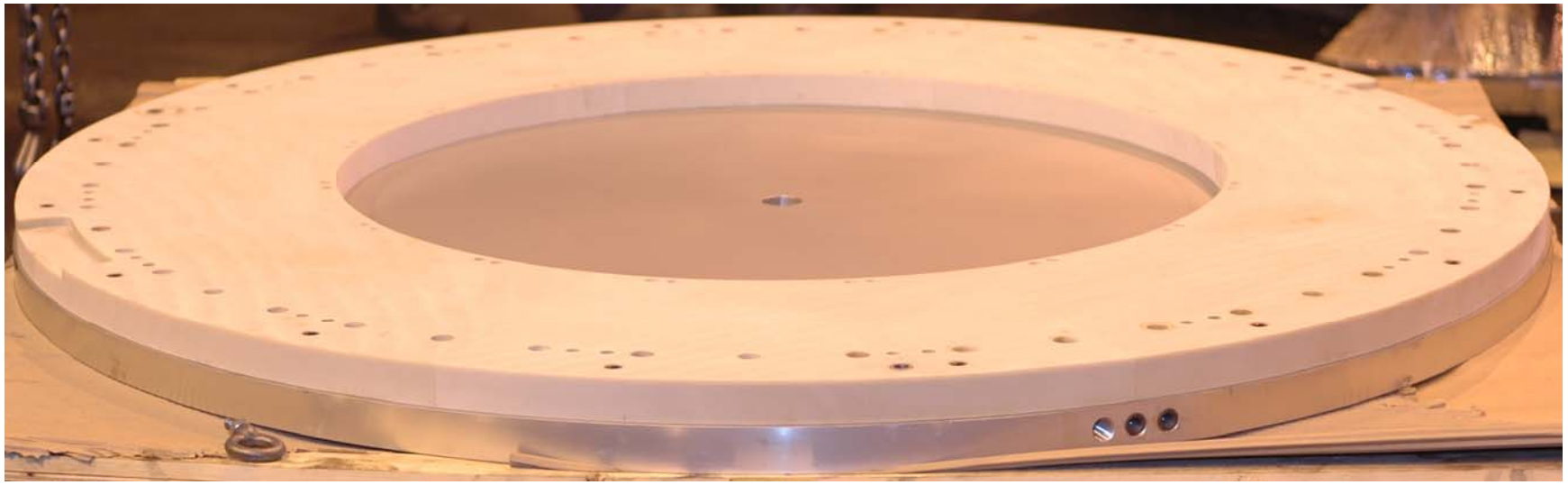




Layout of fluid passages in hot/cold plates

- Each seal cartridge heated/cooled by two hot/cold plates
- Configuration allows each half of seal to be heated or cooled independently:
  - Both seals heated to 50 °C (122 °F)
  - Both seals cooled to -50 °C (-58 °F)
  - One seal at 50 °C, other one at -50 °C
  - Half of each seal heated and other half cooled
- Hot/cold plates heated and cooled by Two Loop Chiller/Heater (Mydax, Inc.)
  - Two separate loops can be controlled independently from -70 to 60 °C (-94 to 140 °F)
  - Heat transfer fluid is Syltherm HF silicone oil (The Dow Chemical Company)

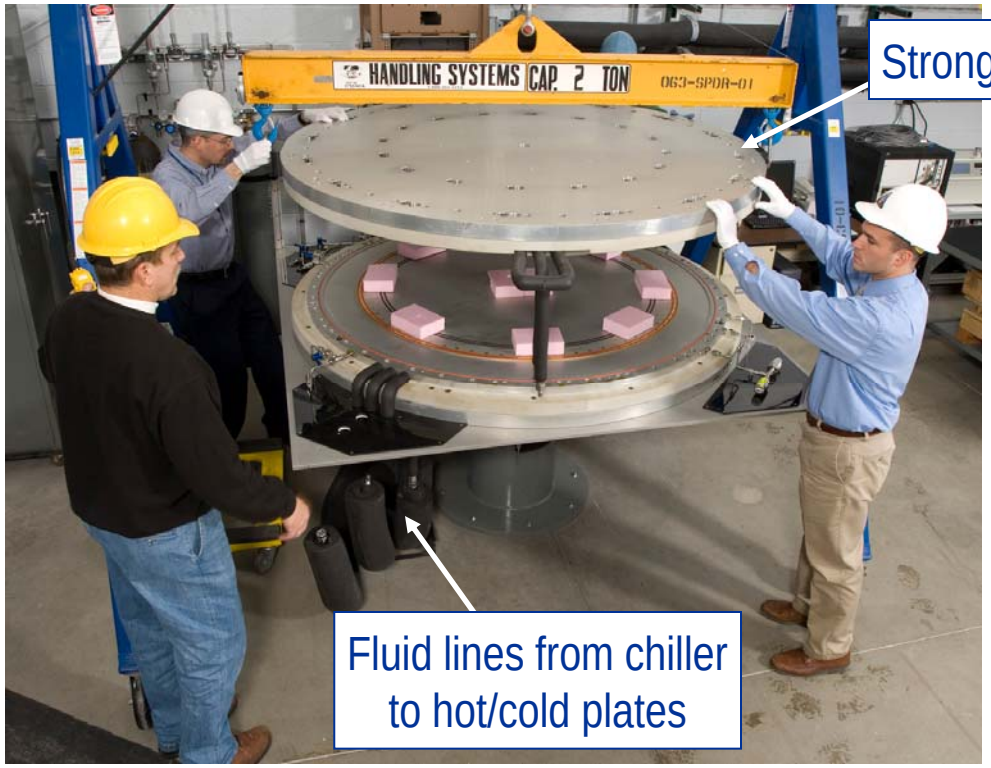
Insulator Plate Assemblies



Insulator plate assembly attached to strongback

- Epoxy-impregnated fiberglass laminate phenolic material (G10 FR4) used as material for insulation
  - High compressive strength (65 ksi) supports seal clamping loads
  - Low thermal conductivity (2 BTU-in/hr-ft²-°F) minimizes heat transfer
- Insulator plate assembly attached to strongback

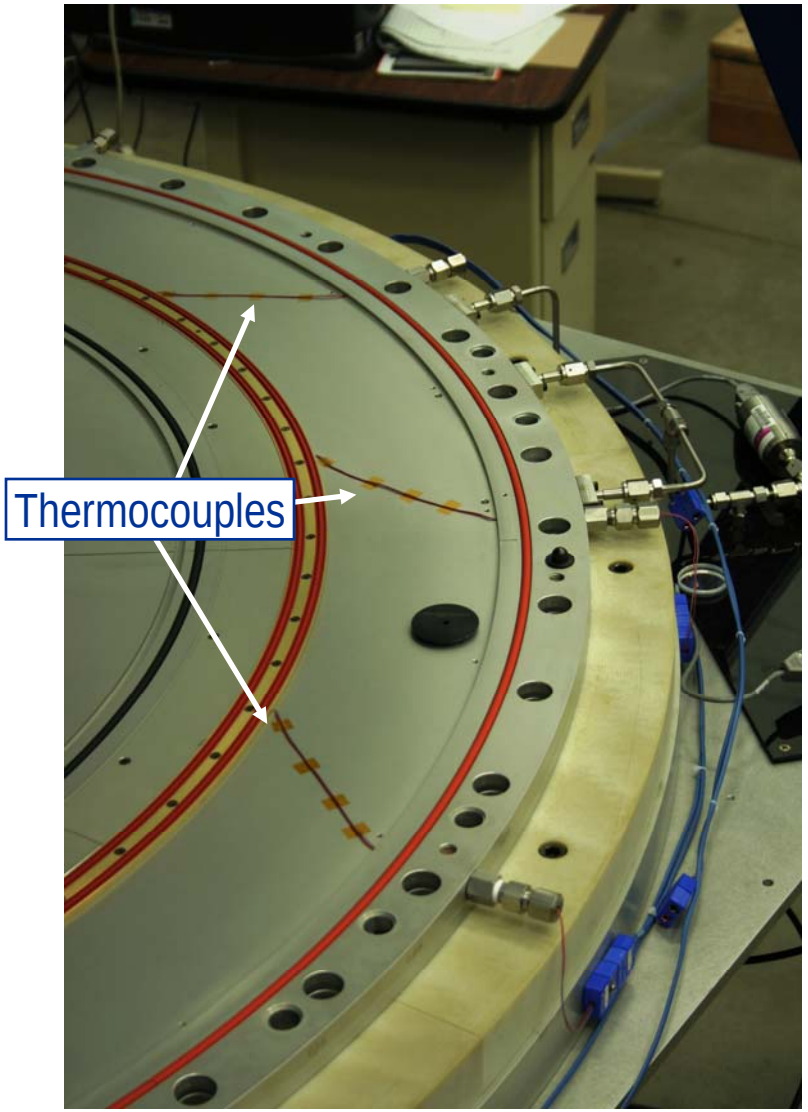
Other Main Elements of Test Rig



- Strongbacks:
  - Main plates to which other assemblies attach (2 in. thick 6061-T651 Al, 75.5 in. diam.)
  - 24 stud/nut assemblies hold upper and lower halves of test rig together
- Hoist attached to overhead gantry crane positions hardware during testing
- Humidity enclosure prevents condensation and ice from forming on rig during cold tests (e.g., -50°C (-58°F))

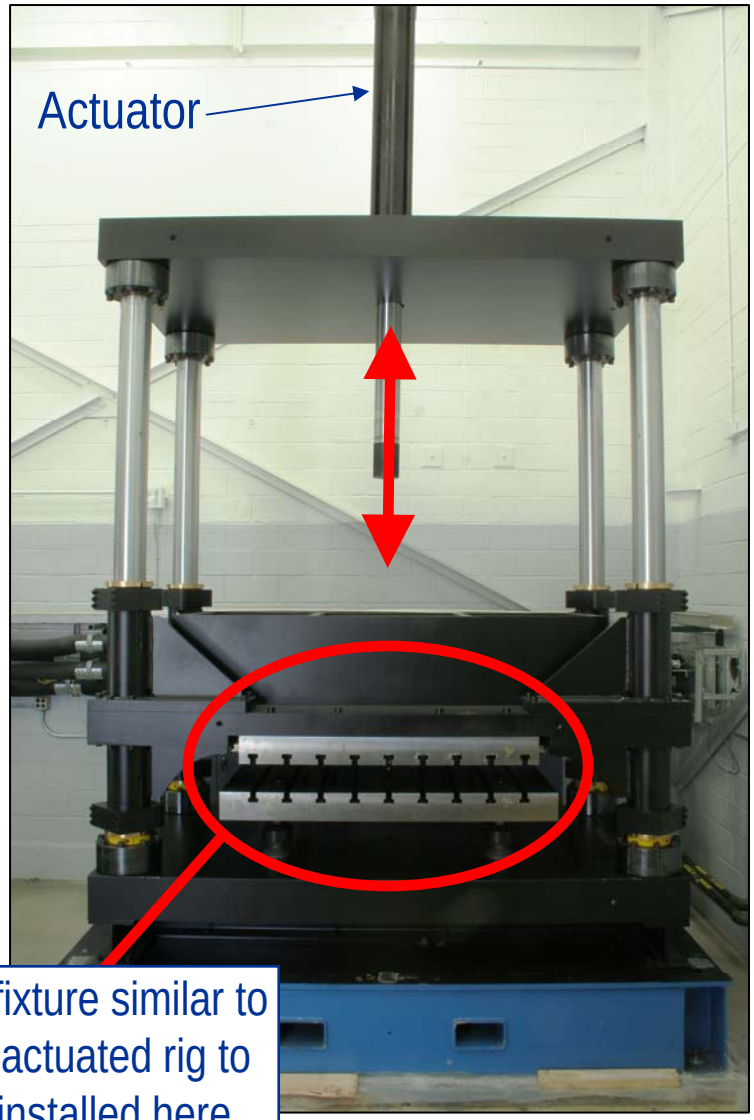
Instrumentation

- Thermocouples:
  - 12 type T thermocouples located 30° from one another measure temperature distribution around each test seal
  - Additional type T thermocouple measures test cell air temperature
- Pressure transducers measure ΔP across seals during testing as well as barometric pressure in test cell
- Seal leak rates measured using two approaches:
  - Pressure decay approach
  - Commercially available helium leak detector



Full-Scale Actuated LIDS Seal Test Rig

- Actuated test rig will measure seal leak rates as well as compression and adhesion forces under simulated LIDS docking approach and separation rates
- Custom load frame from Instron Corp. with double acting/single rod actuator:
  - 54 in. stroke
  - Loads:
    - 112,500 lbf in compression
    - 18,000 lbf in tension



Summary

- NASA is developing LIDS docking system to support future space exploration missions to low-Earth orbit, Moon, and Mars
- GRC supporting JSC by developing LIDS main interface seals
- NASA GRC developing two new test rigs to evaluate performance of candidate full-scale LIDS seals under anticipated operating conditions:
  - Non-actuated rig measures seal leak rates
  - Actuated rig measures seal leak rates and loads
- Status:
  - Non-actuated test rig: Operational
  - Actuated test rig:
    - Load frame delivered to GRC on 7/10/08
    - Test fixture fabrication to be completed late summer at which point it will be integrated into load frame
- Test rigs will be used for seal development and flight qualification tests and to assess on-orbit anomalies if needed

Acknowledgments

- James Lewis and LIDS team from NASA JSC